NJCAT TECHNOLOGY VERIFICATION

STORMWATER MANAGEMENT, INC.

June 2002

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1. Introduction

1.1 NJCAT Program

NJCAT is a not-for-profit corporation to promote in New Jersey the retention and growth of technology-based businesses in emerging fields such as environmental and energy technologies. NJCAT provides innovators with the regulatory, commercial, technological and financial assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization
- Identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated
- Facilitate funding and commercial relationships/alliances to bring new technologies to market and new business to the state, and
- Assist in the identification of markets and applications for commercialized technologies.

The technology verification program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals are formed to implement a comprehensive evaluation of vendor specific performance claims. Thus, suppliers have the competitive edge of an independent third party confirmation of claims.

Pursuant to N.J.S.A. 13:1D-134 et seq. (Energy and Environmental Technology Verification Program) NJDEP and NJCAT have established a Performance Partnership Agreement (PPA) whereby NJCAT performs the technology verification review and NJDEP certifies the net beneficial environmental effect of the technology. In addition, NJDEP/NJCAT work in conjunction to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the verified/certified technology.

The PPA also requires that:

- The NJDEP shall enter in reciprocal environmental technology agreements concerning the evaluation and verification protocols with the United States Environmental Protection Agency, other local required or national environmental agencies, entities or groups in other states and New Jersey for the purpose of encouraging and permitting the reciprocal acceptance of technology data and information concerning the evaluation and verification of energy and environmental technologies; and

- The NJDEP shall work closely with the State Treasurer to include in State bid specifications, as deemed appropriate by the State Treasurer, any technology verified under the energy and environment technology verification program.

1.2 Technology Verification Report

In October, 2000, Stormwater Management, Inc. (SMI), 12021 B NE Airport Way, Portland, Oregon submitted a formal request for participation in the NJCAT Technology Verification Program. The technology proposed - Stormwater Management StormFilter® (StormFilter) - a self-contained storm water filtering system, described in greater detail later in this report, is a technology that can trap particulates and adsorbs dissolved metals and hydrocarbons. The request after pre-screening by NJCAT staff personnel (in accordance with the technology assessment guidelines) was accepted into the verification program. This verification report covers the evaluation based upon the performance claims of the vendor Stormwater Management (see Section 4). The verification report differs from typical NJCAT verification reports in that final verification of the StormFilter technology (and subsequent NJDEP certification of the technology) awaits completed field testing that meets the full requirements of the Technology Acceptance and Reciprocity Partnership (TARP) - Stormwater Best Management Practice Tier II Protocol for Interstate Reciprocity for stormwater treatment technology. This verification report is intended to evaluate Stormwater Management's initial performance claims for the technology based primarily on carefully conducted laboratory studies. These claims are expected to be modified and expanded following completion of the TARP required field testing.

A meeting was held with the vendor and a number of telephone discussions were conducted to solicit relevant materials and to refine specific claims. In particular, it was agreed that SMI would initiate an extensive laboratory study to generate additional data on StormFilter total suspended solids (TSS) removal efficiency for a known soil composition and solids loading. The evaluation is based on reports and conference proceedings provided by Stormwater Management.

1.3 Technology Description

1.3.1 Technology Status: general description including elements of innovation/uniqueness/competitive advantage.

In 1990 Congress established deadlines and priorities for EPA to require permits for discharges of storm water that is not mixed or contaminated with household or industrial wastewater. Phase I regulations established that a NPDES (National Pollutant Discharge Elimination System) permit is required for storm water discharge from municipalities with a separate storm sewer system that serves a population greater than 100,000 and certain defined industrial activities. To receive a NPDES permit, the municipality or specific industry has to develop a storm water management plan and identify Best Management Practices for storm water treatment and discharge. Best Management Practices (BMPs) are measures, systems, processes or controls that reduce pollutants at the source to prevent the pollution of storm water runoff discharge from the site. Phase II storm water discharges include all discharges composed entirely of storm water, except those specifically classified as Phase I discharge. Phase II regulations are currently in draft form for review.

Stormwater Management Inc. (SMI) has developed an innovative storm water treatment system - called StormFilter to meet the requirements of the NPDES. The StormFilter is a passive, flow through, storm water filtration system, improving the quality of storm water runoff by removing non point source pollutants, including total suspended solids (TSS), oil and grease, soluble metals, nutrients, organics, and trash and debris. It has been installed to treat storm water runoff from a wide variety of sites including retail and commercial developments, residential streets, urban roadways, freeways and industrial sites such as shipyards, foundries, etc.

The StormFilter is typically comprised of a vault that houses rechargeable, media-filled filter cartridges. A typical StormFilter configuration is shown in Figure 1. Storm water from storm drains is percolated through media-filled cartridges, which removes particulates and adsorbs materials such as dissolved metals and hydrocarbons. Surface scum, floating oil and grease are also removed. After passing through the filter media, the storm water flows into a collection pipe or discharges to an open channel drainage way. Inherent in the design of the StormFilter is the ability to control the individual cartridge flow rate with an orifice disk placed at the base of the cartridge. The maximum flow rate through each cartridge can be adjusted to between 5 and 15 gpm.

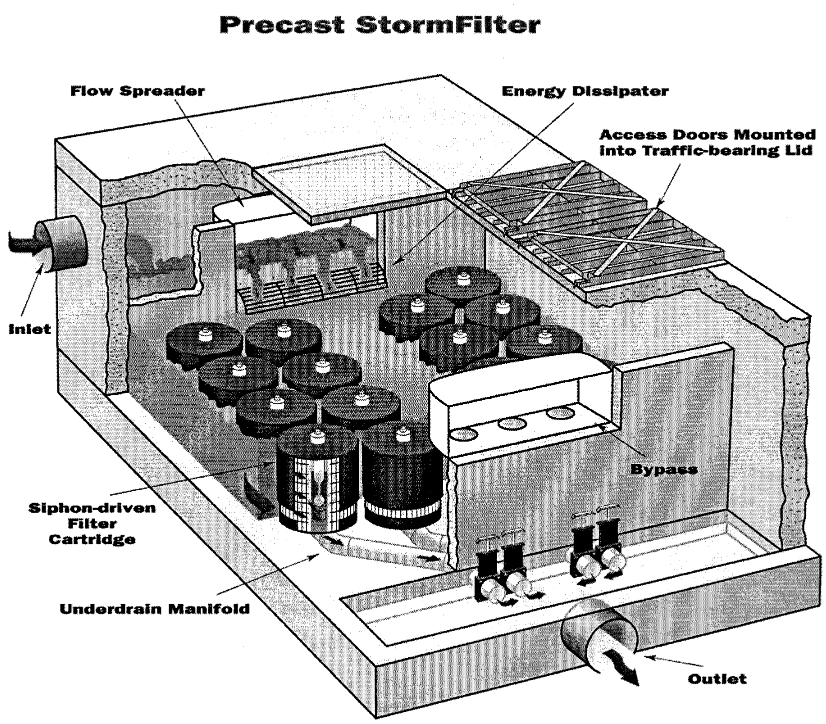

Figure 1 The Precast StormFilter

The StormFilter is sized to treat the peak flow of a design storm as it passes through the system. The peak flow is determined by calculations based on the contributing watershed hydrology and using a design storm magnitude. The design storm is usually based on the requirements set by the local regulatory agency. The particular size of a StormFilter is determined by the number of filter cartridges required to treat the peak water flow.

The StormFilter is offered in five basic configurations: precast, linear, catch basin, cast-in-place, and corrugated metal pipe form. The precast, linear, and catch basin models use pre-manufactured units to ease the design and installation; cast-in-place units are customized for larger flows and may use either uncovered or covered underground units. The corrugated metal pipe units are customized to meet special site requirements.

(1) Precast systems**:** The precast StormFilter is delivered to the site by the precaster and placed in the ground by the contractor. The influent and effluent pipes are connected at this time. Once site work has been completed and ground cover is available, the StormFilter cartridges are delivered and installed. The system is then online.

(2) Linear StormFilter: The Linear StormFilter consists of one or two precast concrete channels that are 10 ft in length and 2 ft 9in. in width. The Linear StormFilter is installed flush with the finish grade, and can function similar to a catch basin or trench drain.

(3) Catch Basin StormFilter: These units are delivered to the site fully constructed (cartridge included) and are plumbed on site. Removal of a 4-in. clean out plug is required to put the system online once construction is complete.

(4) Cast-in-place systems: Cast-in-place StormFilters are cast onsite. The first step is pouring a concrete floor followed by the external and internal walls. The drainage manifold is then secured to the base and a false floor is poured around the manifold to secure it and provide for placement of the cartridges. External walls are then finished and the lid slab is constructed. Once site work has been completed and ground cover is available, the StormFilter cartridges are delivered and installed. The system is then online.

(5) Corrugated Metal Pipe StormFilter: The corrugated metal pipe is used to house StormFilter cartridges. It may be installed online or offline with the storm water collection system.

The typical precast StormFilter unit is composed of three bays: the inlet bay, the filtration bay, and the outlet bay. Storm water first enters the inlet bay of the StormFilter vault. Storm water is then directed through the flow spreader, which traps floatables, oils, and surface scum, and over the energy dissipater into the filtration bay. Once in the filtration bay, the storm water begins to pond and percolates horizontally through the media contained in the cartridges. After passing through the media, the treated water in each cartridge collects in the cartridge's center tube from where it is directed into the outlet bay by an under-drain manifold. The treated water in the outlet bay is then discharged through the single outlet pipe to a collection pipe or an open channel drainage way.

Depending on site characteristics, some systems are equipped with high and/or low flow bypasses. High flow bypasses are installed when the calculated peak storm event generates a flow that overcomes the overflow capacity or design capacity of the system. Base flow bypasses are sometimes installed to prevent continuous inflows caused by groundwater seepage, which usually does not require treatment.

1.3.2 Specific Applicability

The StormFilter utilizes a variety of media to target and remove pollutants from storm water runoff. It is designed to offer a versatile approach to removing site-specific pollutants. By selecting a specific filter media, desired levels of sediments, soluble phosphorus, nitrates, soluble metals, and oil and grease can be removed. In many cases, a combination of media is used to effectively remove storm water pollutants.

(1) CSF® Leaf Media

Stormwater Management uses certified, mature, deciduous leaf compost collected and produced by the city of Portland, Oregon, which resembles granular soil and has no odors. Once processed, the media has physical and chemical characteristics desirable for the filtration of storm water. There are three primary pollutant removal mechanisms performed by the CSF® media. These mechanisms are: mechanical filtration to remove sediments and associated contaminants, chemical processes to remove soluble metals, and adsorption properties to remove oils and greases and other organic compounds.

(2) Perlite

Perlite is a naturally occurring ‘puffed’ volcanic ash. This lightweight material is commonly used as a water filtration media. Although perlite is not chemically active, its highly porous nature, multicellular structure, and rough edges make it very effective for removal of fine particles. Perlite can be used as a stand-alone media or in conjunction with other available media. The primary pollutants targeted by perlite are suspended solids and oil and grease. Perlite, with its many pores and rough edges, is an ideal media for trapping suspended solids. Laboratory and field-testing have demonstrated that perlite is able to capture even fine silt and clay particles while maintaining a robust resistance to clogging by heavy sediment loads. The perlite’s extreme porosity and high surface area allow it to act like a sponge and physically capture free oils and greases as these pollutants flow across its surface.

(3) Zeolite

Zeolites are naturally occurring minerals that have been used in a variety of applications to filter water. Stormwater Management uses a zeolite that has been demonstrated to be useful for removal of cations from storm water runoff. The zeolite can be used as a stand-alone media or combined with other media to target and remove site-specific pollutants. The granular nature of the zeolite allows for removal of suspended solids as the storm water percolates through the macro pores of the media. Microscopic channels within the individual zeolite granules also aid in the removal of silt and clay particles. Removal of soluble heavy metals, such as lead, copper and zinc ions, is facilitated by the cation exchange capacity (CEC) of the zeolite. With a CEC of about 60 meq/100 grams, the zeolite will release light cations, such as calcium and magnesium, and attach heavy metal ions such as lead, copper and zinc.

(4) Other Media

Media can be customized to treat site specific runoff. Some different types of medias that have been used are: iron-infused media to target soluble phosphorus; granulated activated carbon for organics (i.e. pesticides, VOCs); and ion exchange resins (metals removal) associated with industrial storm water. As site conditions change or new standards emerge, new media can be exchanged through routine maintenance.

1.3.3 Range of Contaminant Characteristics

The range of total suspended solids removal using Stormwater Management's filtration media are from 0 mg/L to 700 mg/L according to laboratory and field data. Pretreatment is recommended for excessive solids loading.

1.3.4 Range of Site Characteristics

There are many ways the StormFilter can be configured into the storm water system. The simplest configuration is to install the StormFilter inline with the storm system without any detention, bypass or pretreatment. Different configurations may result from the need to provide pretreatment. In light of the land use, site hydrology, the storm water management plan for the site, and local regulatory requirements, an essential element of the design process is to evaluate pretreatment needs. Pretreatment may include sedimentation vaults or manholes, oil water separators, detention/sedimentation tanks, or high flow and low flow bypasses. The use of storm water Best Management Practices (BMPs) is usually regulated by the local governing agency.

It is important to assess the site conditions before design and installation. Stormwater Management has recommended the following considerations on the uses of StormFilter technology. The lists were created through knowledge of the product and observations made in the field.

(1) Steep slopes - Retaining wall may be required, evaluate for maintenance access.

(2) High groundwater - If discharge is to subsurface infiltration, system may experience backwater. Buoyancy calculations relative to groundwater need to be performed to determine if vault is secure.

(3) Baseflows - Baseflows (a.k.a. dry-weather flows or groundwater flows) need to be bypassed, it may cause growth of algae on filtration media (primarily CSF leaf media) reducing treatment capacity.

(4) Tidal action - Tide may cause backwater into system, tidal valves have been used for this scenario. Design varies with amplitude and frequency of tidal action vs. frequency and depth of filter inundation.

(5) Soils - If stabilization of the vault can be assured, soil conditions are not relevant.

(6) Proximity to wells, septic systems and buildings **-** Groundwater calculations need to be performed for buoyancy issues. Access for maintenance needs to be evaluated. Evaluation of media type within wellhead protection zones is required.

(7) Facility depth limits for access and safety **-** Currently the deepest system is 17 feet. Requirements include standard OSHA (Occupational Safety and Health Administration) confined space entry procedures.

(8) Risks of hazardous material spills **-** The system can be equipped with downstream valves to prevent the loss of material spills. However, the StormFilter is not designed for containment of spills.

(9) Driving head requirements **-** 2.3 feet of drop from inlet to outlet inverts. This can be adjusted with more knowledge of backwater, pipe diameters, and acceptability of pipe submergence. The actual filter driving head is 18 in.

(10) Power availability **-** No power is required

1.3.5 Material Overview, Handling and Safety

Site preparation, filter units delivery, vault construction, and cartridge installation are all general construction practice. There is no handling of hazardous material.

Field personnel should take precautions while handling and installing StormFilter. Field personnel should use appropriate safety equipment, including hardhat and steel-toe boots. Personnel who operate field equipment during the installation process should have appropriate training, supervision, and experience.

The StormFilter vault is considered a confined space such that confined space training is needed to enter the vault. Entry also requires the use of a gas detector for safety. Standard OSHA confined space entry procedures should be followed (29 CFR 1910.146).

1.4 Project Description

This project included the evaluation of assembled reports, conference proceedings, company manuals and literature, and laboratory study reports to verify that StormFilter meets the performance claims of Stormwater Management.

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2 Evaluation of the Applicant

2.1 Corporate History

The mission of Stormwater Management, Inc. of Portland, Oregon, is to develop storm water treatment solutions for engineers, developers and jurisdictional authorities to keep waterways clean. The company has been treating storm water runoff from small commercial sites, large urban mall parking lots, residential streets, and roadways and freeways since 1991.

Stormwater Treatment LLC was formed in 1995 and the company started doing business as Stormwater Management in 1996. After the opening of several regional offices, Stormwater Treatment LLC became Stormwater Management, Inc. in 2000.

The prototype CSF was developed in 1992 and it became "StormFilter" in 1997. The siphon-activated cartridge (patented in 1997) induces radial flow throughout the media cartridge. Multimedia options were introduced to increase the flexibility of the StormFilter system in 1998 and the CatchBasin StormFilter was commercialized in 2000.

Stormwater Management, Inc. also provides technical support to others in analyzing and developing solutions for unique storm water runoff situations.

2.2 Organization and Management

Stormwater Management, Inc.'s principal office is located at 12021 B NE Airport Way Portland, Oregon 97220 with David Pollock as its President and CEO, James H. Lenhart, as its Vice President Research and Development, and Lanz Fritz, as its Chief Financial Officer. Stormwater Management, Inc. has regional offices in California (Chico, CA), the Mid-Atlantic (Gaithersburgh, MD), Western Washington (Seattle, WA), Southeast (Charlotte, NC and Atlanta, GA), and the Northeast (Nottingham, PA and Princeton, MA). The Northeast regional manager is Adam P. Sapp. Presently, Stormwater Management has approximately 50 employees.

2.3 Operating Experience with respect to the Proposed Technology

The StormFilter has been installed in more than 300 locations throughout the country. Currently over 1,000 StormFilter units have been installed using over 14,000 media-filled cartridges in 22 States. Applications range from pre-cast units installed underground in small parking lots for fast food retailers such as McDonalds, to maintenance facilities and high tech industry. The initial design won an engineering and environmental excellence awards from the American Consulting Engineers Council in 1992. Oregon Entrepreneur Forum honored Stormwater Management with the Emerging Company of the Year award in 2001. Stormwater Management was awarded the 2002 BEST (Businesses for an Environmentally Sustainable Tomorrow) Award recognizing its efforts in the area of sustainable product development.

2.4 Patents

Stormwater Management has four patents on their products, including CSF leaf media, siphon-actuated cartridge, and self-cleaning mechanism.

2.5 Technical Resources Staff and Capital Equipment

Stormwater Management has developed a product manual for design, installation, and operation and maintenance of StormFilter. The manual provides an overview of StormFilter, applications of the technology, system design considerations, pretreatment requirements, detailed design procedures, operation and maintenance guidelines, and a number of design drawings.

The manual contents assume that the designer has a background in civil or environmental engineering, but provides the necessary detail and calculation support to assist in sizing and siting the StormFilter. Stormwater Management has also created a CD Rom, which contains the product design manual and a PowerPoint presentation of the StormFilter technology.

Stormwater Management provides full engineering services for the design of the StormFilter. These services are provided to the design engineer and the plan reviewer. Stormwater Management also provides all components to the StormFilter including cartridges, flow spreaders, energy dissipaters and drainage manifold. . Pre-cast vaults are also supplied by Stormwater Management. Contractors will construct cast-in -place systems after inspection and approval by Stormwater Management. (Stormwater Management provides all components for cast-in-place systems.). It takes 4 to 6 weeks to install the precast systems or cast-in-place-systems. Many precasters throughout the nation can provide the StormFilter vault. The design life of the structure is typically 50 years. Stormwater Management provides for cartridge installation and final observation.

Stormwater Management provides long-term support and maintenance to the land owner/operator. (See Section 5.3 for recommended maintenance requirements.)

3. Treatment System Description

Filtration is of interest for the treatment of storm water runoff because the filters will work on intermittent flows without significant loss of capacity and they do not require a large above ground surface area. Filters are primarily installed in new development and redevelopment, and may be installed into urban areas provided there 2.3 feet of drop from inlet to outlet. Sand, activated carbon, peat-moss, zeolite, compost and waste product have been used as filter media (Clark et. al., 1997). As new media become available, the system is easily upgraded with new media through a routine maintenance cycle.

Stormwater Management offers a filtration technology that is easy to design and easy to install. Storm water flows through filter cartridges containing various media and the filter media traps and absorbs pollutants. After passing through the filter media, the storm water discharges to a drainage way.

The StormFilter cartridge is the central treatment device within the system. The cartridges are filled with various media depending on the site's runoff. Removal associated with the cartridge is promoted through four mechanisms: physical straining, ion exchange, adsorption, and precipitation.

Physical straining through the media promotes solids removal by trapping solids within interstitial spaces throughout the filtration media. Depending on the media used, dissolved pollutant removal is either associated with ion exchange, adsorption or precipitation reactions.

Ion exchange involves the displacement of ions within the filtration media by ions in the influent stream. The process used by SMI is cation exchange where calcium, magnesium and sodium ions within the filtration media are displaced by ions such as copper, zinc and lead.

Adsorption is a surface reaction where a pollutant is fixed to the filtration media as the pollutant crosses the media's surface. These reactions are usually promoted by polar interactions between the media and the pollutant. In other words, the media may be slightly negative where the pollutant is slightly positive. The interaction is similar to a magnet and occurs primarily at the media's surface.

Precipitation reactions also occur within the filtration media's structure. This involves the exchange, or sharing, of electrons between atoms and molecules to form a solid on the media's surface. In a sense, salts are formed on the media due to the electron interaction.

Sizing is based on the design storm designated by the specific regulatory agency. Flows resulting from a design storm are used to calculate the number of cartridges designed to a 5 to15 gpm per cartridge flow rate. Once the numbers of cartridges are known the facility is sized.

Inspection of the filter performance and assessment of the maintenance can be conducted easily. There is no need of special equipment for filter installation and maintenance. Maintenance of the system involves changing the cartridges and removing sediment. Typical life of a cartridge has been budgeted at 20 years.

4. Technical Performance Claims

Claim 1 - The StormFilter cartridge at 15 gallons per minute (gpm) using a coarse perlite media has been shown to have a TSS removal efficiency of 79% with 95% confidence limits of 78% and 80%, respectively for a sandy loam comprised of 55% sand, 40% silt, 5% clay (USDA) in laboratory studies using simulated storm water.

Claim 2 - The StormFilter cartridge at 7.5 gallons per minute (gpm) using a combination of fine and coarse perlite media has been shown to have a TSS removal efficiency of 71% with 95% confidence limits of 68% and 75%, respectively for a silt loam comprised of 15% sand, 65% silt, 20% clay (USDA) in laboratory studies using simulated storm water.

Claim 3 - The StormFilter cartridge at 15 gpm using CSF® leaf media has a TSS removal efficiency of 73% with 95% confidence limits of 68% and 79%, respectively when evaluating field and laboratory data.

5. Treatment System Performance

StormFilter has been tested in the laboratory and applied at over 300 locations in the field. These field demonstrations have ranged from pre-cast units installed underground in small parking lots to 18 miles of 6-lane freeway. Fourteen (14) of these applications have been documented in various publications and conference proceedings. The above provides the foundation upon which the Stormwater Management claims are evaluated.

5.1 StormFilter Case Studies and Laboratory Studies

Four (4) case studies are presented below. The case studies are intended to provide the reader a perspective on the range of StormFilter applications. Performance data for most of these sites were not provided by Stormwater Management. Only field data from Case Study 4 is cited in support of Stormwater Management's claims. These descriptions give a history of the site, the specific objectives for the project, and the time and duration of the project . In addition, Stormwater Management has conducted significant laboratory testing in preparing their claims.

Case Study 1 – Costco Wholesale Corporation, Clackamas, Oregon

Costco Wholesale constructed a large membership warehouse store in Clackamas, Oregon. This 14-acre site included a 136,000 square foot building with a parking capacity for 800 vehicles. Portions of the property were within a 100-year floodplain of Kelly Creek. To mitigate flood plain impacts, Costco needed to purchase a 4-acre wetland, 3 acres of natural habitat and an additional 8 acres of land to construct a new 70,000 cubic foot floodwater storage area. Costco was also required by Clackamas County to detain flows from the 10-year storm from the developed property to the 5-year undeveloped peak flow. This required the design of a large storm water detention system. The County also required that all runoff leaving the developed site be treated prior to discharging into the wetlands (Stormwater Management, 2002d).

Due to the severe land constraints and the high water table that prohibited additional ponds and swales, a storm water management system was designed and installed. Runoff from the site is directed to large underground detention tanks below the water table surface. The tanks consisted of 2,200 lineal feet of 48” and 72” pipe with a detention storage capacity of 41,000 cubic feet. A storm water lift station pumps storm water from the tanks into the StormFilter which was situated above the groundwater table.

Two StormFilter units (CSF filter media) were situated on different parts of the property to treat runoff from those areas. One unit containing 24 radial flow filter cartridges, treats 0.64 cfs (287 gpm) from 10.34 acres of impervious surface area. The second unit with 14 radial flow cartridges that treats 0.33 cfs (148 gpm) from 3.9 acres. Both StormFilter units discharge the treated storm water directly into nearby wetlands, which feed nearby Kelly Creek.

Case Study 2 – Community Transit Bus Maintenance Facility, Everett, Washington

Community Transit (CT) needed to construct the Community Transit North Base in Everett to provide for the maintenance for 420 busses and parking for 380 cars. The offices and shops were combined into an 87,000 square foot building. The entire project site encompasses 22 acres of mostly concrete and asphalt (Stormwater Management, 2002d).

The quality of storm water runoff from this site was of concern because it discharges to adjacent wetlands and waterways, which are sensitive to urban pollutants. Due to the limited space on the site, the use of traditional storm water treatment technologies such as ponds and swales was not practical. The treatment objectives were to minimize the impacts to the wetlands from sediments, oils and greases, and heavy metals, which are normally associated with runoff from paved surfaces.

With these design constraints in mind the site civil engineers specified StormFilter (CSF filter media). Containing 120 siphon actuated filter cartridges this facility was designed to treat 4 cfs (1,795 gpm) from the site, which constitutes the runoff resulting from a 6-month storm.

Developed by Quadrant Corporation and constructed by GLY Construction of Bellevue, Washington, this project won the 1997 Washington State Development of the Year award by the National Association of Office and Industrial Properties (NAIOP).

Case Study 3 – City of Olympia, Washington

The City of Olympia, Washington constructed a StormFilter as a test project in 1996. The system treats runoff from a 200-acre watershed comprised of mature commercial and residential developments and roadways. Much of the runoff is conveyed along roadways with no curbing. This fact contributes to high amounts of sediment loading at the site (Stormwater Management, 2002d).

The StormFilter contains 80 cartridges in a cast in place unit measuring 12’ x 37’. The cartridges are housed in two vaults, 40 cartridges each, which fill at equal rates. The system has a small settling pond prior to the filter. Each cartridge is designed to treat 15 gpm.

Approximately two hours into a rain event on April 23, 1998, samples were taken within the cartridge bay and of effluent from the two perlite media drainage lines and a CSF® leaf media line. (The drainage lines are separated for monitoring purposes.) The samples were analyzed for total suspended solid (TSS), total phosphorus (TP), dissolved phosphorus (DP), total metals and dissolved metals.

Case Study 4 – McDonald’s, Vancouver, Washington

McDonald’s located in Vancouver, Washington has approximately one acre of impervious area draining to a 9-cartridge StormFilter. The StormFilter is a precast unit measuring 6’x12’ with a designed peak treatment flow of 0.3 cfs (134.6 gpm). Each cartridge is designed to treat 15 gallons per minute (gpm). The site has no pretreatment. CSF leaf media, perlite media, and fabric with perlite media were maintained at various periods during monitoring (Stormwater Management, 2002d).

Samples were taken by time pacing at approximately 30-second intervals. One sampler took 6 samples of the influent while another sampler took 6 samples of the effluent lines. These samples were later mixed thoroughly and combined to produce 2 samples. Analysis of total suspended solids (TSS), dissolved phosphorus, total phosphorus and oil and grease was performed.

Laboratory Studies

The StormFilter cartridge configuration chosen for laboratory studies was the perlite StormFilter cartridge operating at 15 gpm and 7.5 gpm. Cartridge-scale tests were conducted in the laboratory environment using simulated storm water.

The test apparatus used for this experiment simulates the filtration bay component of a full-scale StormFilter system, including the energy dissipator. The test apparatus is shown in Figure 2. Influent and effluent storage was provided by individual 250 gallon, conical bottom, polyethylene tanks (Chem-Tainer). Suspension of solids within the tanks was maintained by individual, 1/2- hp, electric, propeller mixers (J.L Wingert, B-3-TE-PRP/316). Peristaltic-type pumps (Vanton, 5 gpm Flex-i-liner) were used to recirculate water through the underlying manifolds of both tanks during sampling so as to eliminate any possibility of sediment accumulation in the manifolds.

Influent was carried from the influent tank by two peristaltic-type pumps (Vanton, 10 and 5 gpm Flex-i-liner) plumbed into a common PVC intake manifold below the influent tank and discharged into a common delivery manifold of 1” PVC pipe. The delivery manifold was connected to the 22” x 22” x 24.5” (LxWxH) polypropylene StormFilter cartridge test tank. Discharge from the StormFilter cartridge test tank into the effluent tank was through direct discharge from the under-drain manifold component of the test tank over the top of the effluent tank.

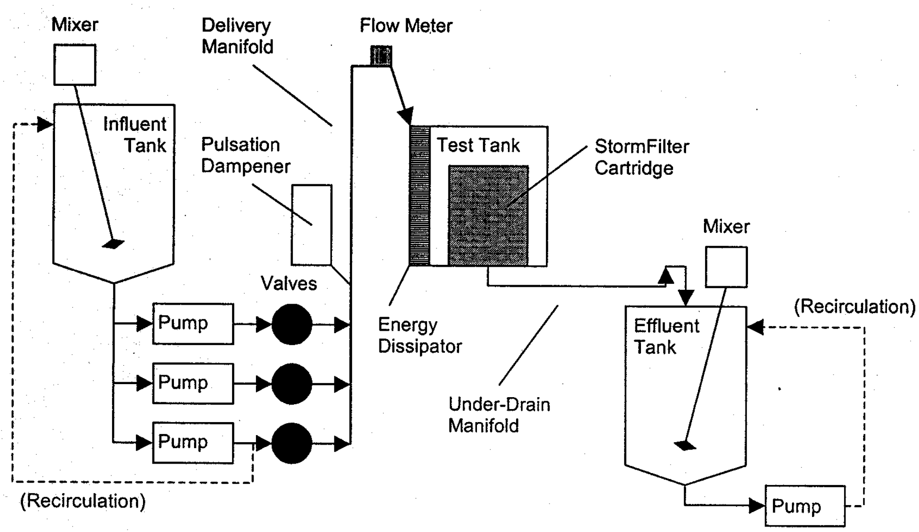

Figure 2 Schematic Diagram of the Test Apparatus

The suspended solids used in the experiment were supplied through the addition of a mixture of sand, silt, and clay soil to the influent. Following preparation of the bulk sample, particle size analysis was performed internally using hydrometer and sieve techniques (Gee and Bauder, 1986). This particle size distribution is much finer than that recommended by APWA (American Public Works Association, 1999) and Portland BES (Portland Bureau of Environmental Services, 2001) for laboratory performance testing. Two sets of a simulated storm water test were performed and the testing conditions are shown in the following table.

Table 1 Laboratory Studies

	Test 1	Test 2
Filter media	Coarse perlite	Combination of fine & coarse perlite
Filtration flow rate	15 gpm	7.5 gpm
Particle size distribution of the suspended solids	55% sand, 40% silt, and 5% clay	15% sand, 65% silt, 20% clay
No. of simulated storm water tests	21	21

TSS is defined according to EPA method 160.2 with the additional constraint of a maximum particle size of 1000 um (1 mm). This definition of TSS is in accordance with APWA (1999) and Portland BES (2001) protocols for the laboratory testing of stormwater treatment technologies. To generate a conservative result of StormFilter performance in the field, synthetic or refined silica-based materials were not used for testing due to their high density and uniform sphericity. Instead, actual soil was used, thus providing the range of particle sizes, shapes, and densities of a material that might actually erode or otherwise become entrained by stormwater runoff. Figures 3 and 4 show the particle size distribution for bulk soil samples used for Tests 1 and 2. Dashed and dotted lines indicate the particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

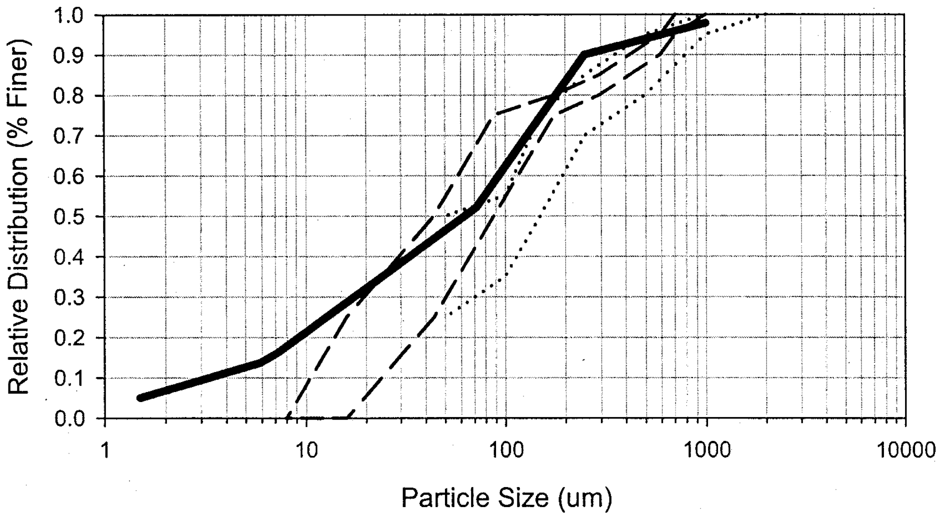

Figure 3 Particle Size Distribution for Bulk Soil Sample Used in Test 1

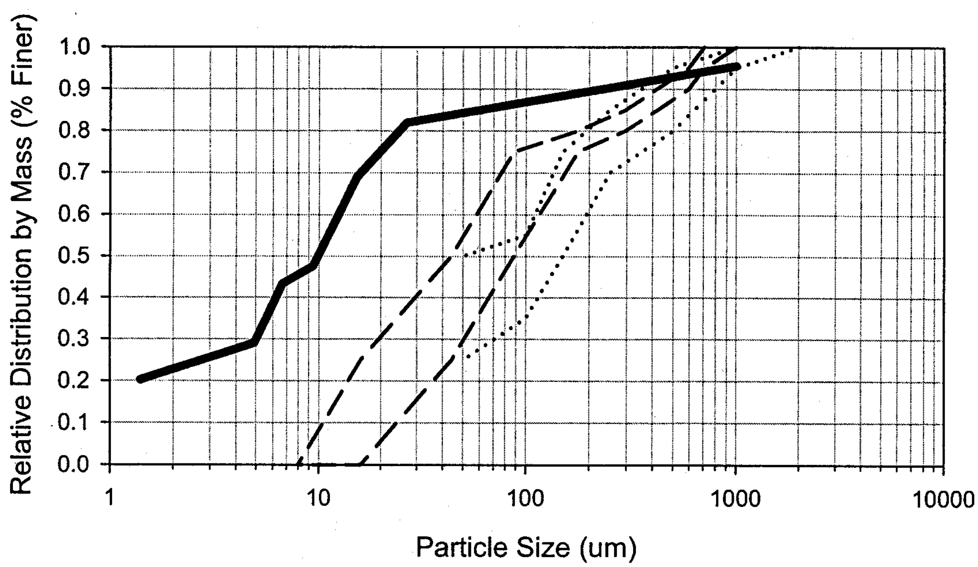

Figure 4 Particle Size Distribution for Bulk Soil Sample Used in Test 2

The influent tank was filled with 210 gallons (800 L) of tap water, and the predetermined contaminant concentrate was added to the influent tank. The influent tank was then mixed thoroughly with the mechanical mixer while influent was re-circulated through the lowest port in the underlying manifold and allowed to equilibrate for 5 to 10 minutes before sampling.

Following influent sample collection, re-circulation was stopped and the influent was pumped into the test tank energy dissipater via the delivery manifold. Flow rate was controlled through periodic adjustment of the influent flow valves so as to maintain a constant flow rate. Mixing and re-circulation of the effluent reservoir was started towards the end of a run to allow effluent equilibration prior to sample collection.

The influent pumps were operated until as much of the influent had been pumped from the influent reservoir and underlying manifold as was possible, at which point the influent pumps were shut down and the StormFilter cartridge test tank was allowed to drain. Once the float valve within the StormFilter cartridge closed, effluent was sampled and the total run volume reported by the totalizer was recorded.

Composite samples of entire influent and effluent volumes were collected for both TSS and particle size analysis. Sample handling was performed in accordance with standard handling techniques; all samples were promptly refrigerated following collection, shipped in ice packed coolers to the appropriate laboratories for analysis within seven days, and accompanied by chain-of-custody documentation. Severn Trent Services (Tacoma, WA) was employed to provide TSS analysis according to EPA method 160.2 (US EPA, 1999), and Chemoptix Microanalysis (West Linn, OR) was used to perform the particle size analysis according to ASTM method F312-97, an optical technique.

Data were collected from laboratory experiments and these data can be evaluated to assess the validity of Claims 1 and 2.

5.2 Verification Procedures

Stormwater Management, Inc. working with various environmental and consulting firms has applied StormFilter at over 300 locations. All of these are full flow installations or pilot demonstrations; only fourteen (14) monitoring results demonstrations have been published, none in peer-reviewed journals. Most of the publications are conference proceedings, company technical updates, and technical reports. QA/QC procedures for most of the field data presented are unknown. However, sufficient information exists to support verification of the claims submitted.

Claim 1 – The StormFilter cartridge at 15 gallons per minute (gpm) using a coarse perlite media has been shown to have a TSS removal efficiency of 79% with 95% confidence limits of 78% and 80%, respectively for a sandy loam comprised of 55% sand, 40% silt, 5% clay (USDA) in laboratory studies using simulated storm water.

Data were collected from a laboratory experiment as described in Section 5.1 Laboratory Studies - Test 1. These data can be evaluated to assess the validity of Claim 1.

This experiment measured the 55% sand, 40% silt, and 5% sandy loam TSS removal efficiency of a coarse perlite StormFilter operating at 15 gpm. Twenty-one (21), cartridge-scale tests were conducted in the laboratory environment using simulated storm water with TSS influent concentrations ranging between non-detect (ND) and 301 mg/L. Six (6) of the 21 events were sampled in duplicate to increase the overall accuracy of the experiment. The 15 gpm filtration rate represents the 100% design filtration rate specified per cartridge for the treatment of a design storm event by an actual StormFilter system.

Linear regression statistics similar to those suggested by Martin (1988) and URS et al. (1999) were used to estimate the mean TSS removal efficiency (de Ridder et al., 2002a). Instead of using calculated TSS load values as suggested by Martin (1988), regressions were performed on EMC (Event Mean Concentration) values alone so as to avoid any error associated with the volume data. Also the y-intercept of the regression was not constrained to the origin as suggested by Martin (1988). This addressed the concerns of URS et al. (1999) and allowed the estimation of the mean irreducible effluent TSS concentration (Center for Watershed Protection, 1996).

As shown in Figure 5, the coefficient of determination (r^2) of 0.98 indicates a strong dependence of effluent TSS EMC on influent TSS EMC. The regression coefficient (the slope of the linear regression, 0.21) can represent the mean TSS removal inefficiency, 21%. Subtracting the regression coefficient from 1 yields the mean TSS removal efficiency, 79%. Dotted lines represent upper and lower 95% confidence limits of 80% and 78%, respectively, for the regression. Three additional lines, 0, 50, and 100% efficiency, are provided for comparison. The removal of silted-size particles as small as 5-15 µm was also observed.

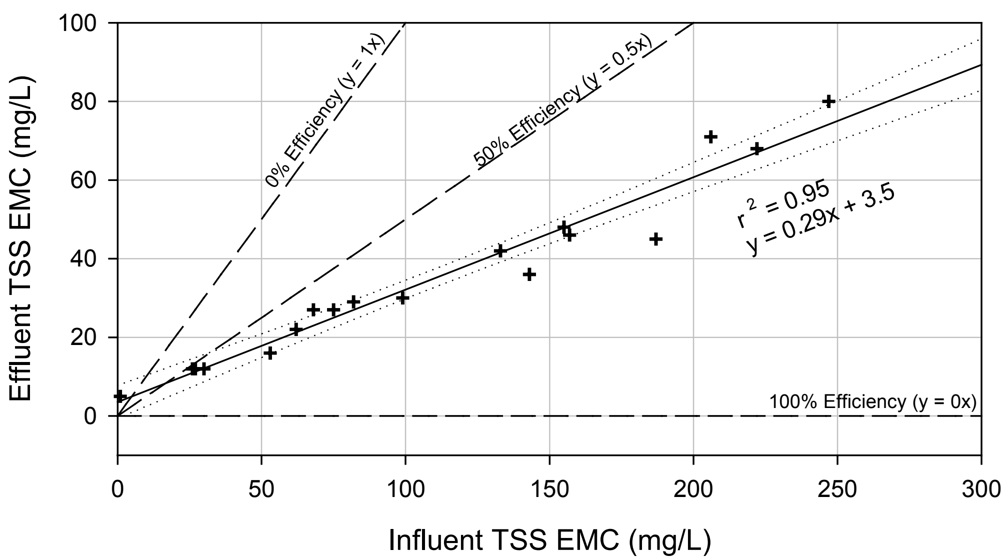

Figure 5 Plot of Influent TSS EMC and Corresponding Effluent TSS EMC for a Coarse Perlite StormFilter Cartridge Test Unit Operating at 15 gpm for TSS with a Sandy Loam Texture (55% Sand, 40% Silt, 5% Clay by Mass)

It should be noted that the mean TSS removal efficiency estimate only holds true for the system under evaluation (i.e., TSS removal by cartridge filtration alone). For example, the effect of the inlet bar or the pretreatment on TSS was not included.

Claim 2 - The StormFilter cartridge at 7.5 gallons per minute (gpm) using a combination of fine and coarse perlite media has been shown to have a TSS removal efficiency of 71% with 95% confidence limits of 68% and 75%, respectively for a silt loam comprised of 15% sand, 65% silt, 20% clay (USDA) in laboratory studies using simulated storm water.

Data were collected from a laboratory experiment as described in Section 5.1 Laboratory Studies - Test 2. These data can be evaluated to assess the validity of Claim 2.

This experiment assesses the ability of a Stormwater Management StormFilter cartridge configured with a combination of coarse and fine perlite media to remove total suspended solids (TSS) with a silt loam texture (15% sand, 65% silt, 20% clay) at a filtration rate of 7.5 gpm (100% design, per cartridge, operating rate for this configuration). Twenty-one (21), cartridge-scale tests were conducted in the laboratory environment using simulated storm water with TSS influent concentrations ranging between non-detect (ND) and 247 mg/L. Five (5) of the 21 events were sampled in duplicate to increase the overall accuracy of the experiment.

Several data were discarded due to the incompatibility of the EPA method 160.2 sample-splitting technique with sand-bearing TSS samples based upon both internal observations and the recommendations of Gray et al. (2000). With the data set defined, 18 runoff simulations were used for linear regression statistics to estimate the mean TSS removal efficiency (de Ridder et al., 2002b).

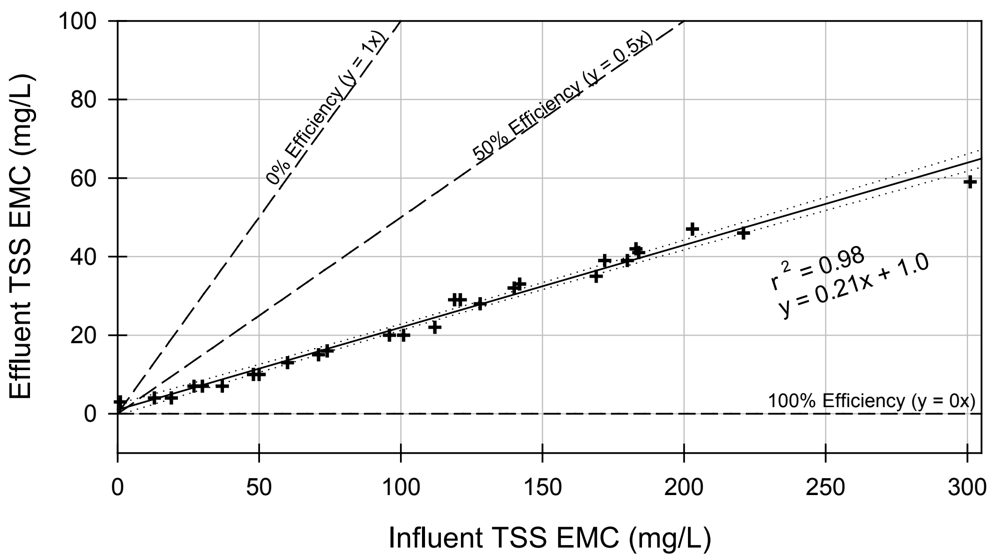

Figure 6 Plot of TSS Removal Efficiency vs. Influent TSS EMC for a Coarse/Fine Perlite StormFilter Cartridge Test Unit Operating at 7.5 gpm for TSS with a Silt Loam Texture (15% Sand, 65% Silt, 20% Clay by Mass)

As shown in Figure 6, the coefficient of determination (r^2) of 0.95 was obtained in the regression analysis TSS EMC. The regression coefficient (the slope of the linear regression, 0.29) is used to represent the mean TSS removal inefficiency, 29%. Subtracting the regression coefficient from 1 yields the mean TSS removal efficiency, 71%. Dotted lines represent upper and lower 95% confidence limits of 75% and 68%, respectively, for the regression. Three additional lines, 0, 50, and 100% efficiency, are provided for comparison. It was observed that the perlite StormFilter is capable of removing TSS down to 25 μm for TSS with a silt loam texture and 7.5 gpm filtration rate.

The mean TSS removal efficiency estimate is true for the system under evaluation (i.e. the TSS removal efficiency of the cartridge filtration). The effect of the inlet bar or the pretreatment was not included.

Based on an interpretation of these laboratory data using simulated storm water, the StormFilter cartridge at 7.5 gpm using a fine/coarse perlite media is expected to be able to achieve an 80% TSS removal for an approximate soil texture comprised of 30% sand, 50% silt, and 20% silt (USDA). The reasoning is as follows:

> Mass density plays an integral role in the removal of suspended solids. The larger sand particles have a greater mass than the silt sized particles. Reducing the less dense silt material from Claim 2 by a conservative 15% mass, and increasing the sand mass by 15%, the overall mass density would increase significantly. Since StormFilter performance increases with a particle's mass density (Claim 1), the TSS removal efficiency is expected to increase.

Claim 3 – The StormFilter cartridge at 15 gpm using CSF® leaf media has a TSS removal efficiency of 73% with 95% confidence limits of 68% and 79%, respectively when evaluating first flush, composite, and laboratory data.

The CSF leaf media has been in use throughout the US since the Washington County demonstration project in 1992. Data have been collected from multiple sites and from laboratory studies that used a StormFilter containing CSF leaf media The data have been assimilated from the following documents: Burwell/Straley's six storms (Stormwater Management, 2001); Wigginton and Lenhart (1998); McDonald's (Wigginton, 1998a); and Southwest Bible Church (Wigginton 1998b); and TSS Removal Using StormFilter Technology (Stormwater Management, 2000a). The cartridge flow in all cases was 15 gpm.

Field and laboratory data were analyzed together to increase the sample population to determine a representative regression coefficient. A linear regression analysis was performed on these data (Stormwater Management, 2002a). These data can be evaluated to assess the validity of Claim 3.

Data from these sources were plotted as influent compared to effluent concentration shown in Figure 7. This figure shows a scatter plot of the data and the linear regression. The lower coefficient of determination (r^2) is attributed to the variability of the field sampling or storm water characteristics such as particle size. Under the assumption that there is no difference between field and laboratory, the StormFilter operating at 15 gpm with compost CFS media functioned with 73% removal efficiency. At a confidence interval of 95%, the lower and upper limits for the regression coefficient were 68% and 79%, respectively (Stormwater Management, 2002a).

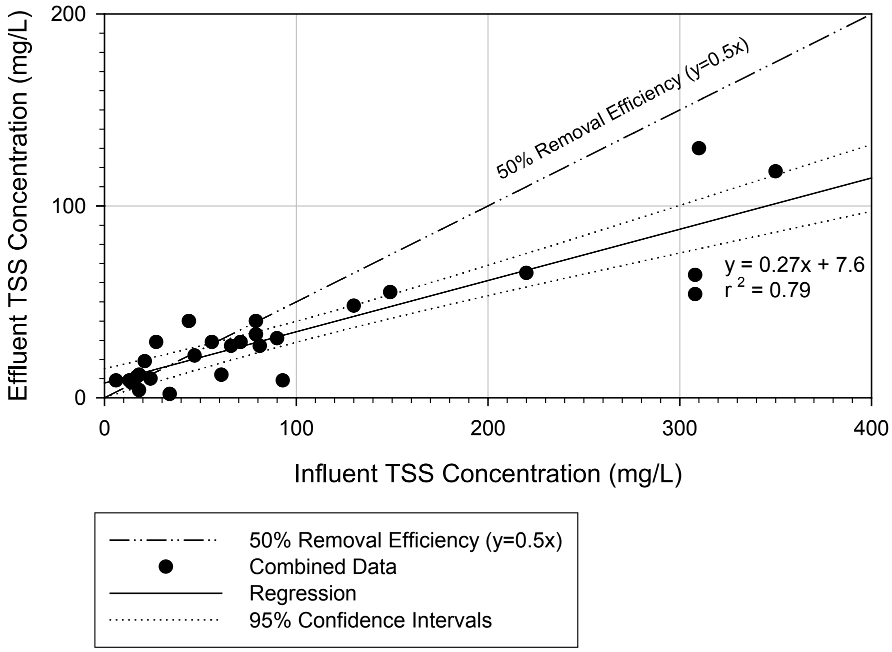

Figure 7 Combined (Field and Laboratory) CSF Leaf media Performance Evaluation

Additional Pollutant Removal Capacities

Urban storm water often contains high levels of soluble and particulate heavy metals generated from traffic, industrial facilities, and, sometimes, residential sources. Two of the most common metals found in the storm water are zinc and copper. Metals are measured as both total metals and soluble metals. Soluble metals are commonly defined as those metals that pass through 0.45-micron filter. Metals can be removed from the storm water by ion exchange. Ion exchange is the exchange of a cation (in the media matrix) for another cation in the water. The displacement occurs if the incoming atom's affinity for the exchange site is higher than that of the current occurring atom.

Oils and greases (O&G) are commonly found in storm water runoff from automobiles and associated anthropogenic activities. O&G appears in many forms in storm water runoff: free, solubilized, emulsified, and attached to sediments. Total petroleum hydrocarbons (TPHs) are the usual analytical measure of O&G for storm water. Typically the concentrations of TPH associated with runoff from streets and parking lots range from 2.7 to 27 mg/L (Federal Highway Association, 1996).

The StormFilter cartridge with various filtration media (e.g. CSF leaf media, XFCSF leaf media, perlite media) has shown the capability to remove heavy metals and total petroleum hydrocarbons (TPHs) in field and laboratory studies, as indicated below. Claims regarding removal efficiencies for heavy metals and TPHs are anticipated to be generated following Tier II testing.

(1) CSF Leaf Media

The StormFilter using CSF leaf media and operating at 15 gpm was analyzed for its ability to remove dissolved zinc. Field and laboratory test data were analyzed to estimate system performance (Clark, et al., 1997; Stormwater Management, 2001; Stormwater Management, 2000b; Tobiason, et al., 2001).

Table 2 shows the results for dissolved zinc removal using CSF leaf media (Stormwater Management, 2002b). Field data contained a narrow distribution of influent concentration and laboratory data contained a wide distribution of influent concentrations: first flush (0.078 to 0.27 mg/L), composite (0.07 to 0.25 mg/L), and laboratory (0.003 to 0.988 mg/L).

Table 2 Dissolved Zinc Removal at 15 gpm Using CSF Media (Stormwater Management, 2002b)

Data type	Samples	Influent Conc. (mg/L)	Weighted average removal
First flush	6	0.078 - 0.27	56
Composite	6	0.07 - 0.25	50
Laboratory[1]	12	0.003 - 0.988	44

1. Data taken from Tobiason et al. (2001)

As shown in Table 2, weighted average removals for dissolved zinc were between 44 and 56%.

(2) XFCSF Media

The extra-fine grade CSR media (XFCSF) was developed as an enhanced performance alternative to the coarse grade CSF media. The XFCSF media is able to increase removal of dissolved metals because of an increased media surface area, decreased pore size, and increased residence within the media.

The StormFilter using the XFCSF leaf media and operating at 15 gpm and 6.5 gpm, independently, was analyzed for its ability to remove dissolved zinc and copper. Laboratory test data were analyzed for effectiveness in removing zinc and copper for shipyard and other industrial applications (de Ridder, 2001).

Eight samples were evaluated for dissolved zinc (concentrations 0.013 to 1.07 mg/L) at 15 gpm. Forty samples each were analyzed for dissolved copper (concentrations 0.01 to 19.0 mg/L) and dissolved zinc (concentrations 0.023 to 27.0 mg/L). Linear regression analysis was performed and weighted average removal efficiency was calculated (Stormwater Management, 2002c). Table 3 shows the results.

Table 3 Weighted Average Analysis and Linear Regression Analysis Using XFCSF Media (Stormwater Management, 2002c)

Metal	Flow rate (gpm)	Concentration (mg/L)	Samples	Weighted Ave. Removal (%)	Linear Regression Efficiency (%)
Cu	6.5	0.010 – 19.0	40	93.4	96.7
Zn	15	0.010 – 17.0	8	68.5	72.0
Zn	6.5	0.003 – 1.07	40	96.3	95.6

Although greater than 90% removal was demonstrated in the laboratory with XFCSF leaf media operating at 6.5 gpm for both dissolved copper and zinc; the presence of other metals and changes in temperature, redox potential, pH etc. in the field may decrease performance. Table 4 is the anticipated performance of XFCSF leaf media (de Ridder, 2001).

Table 4 Anticipated Range of XFCSF Media Removal Efficiency at 6.5 gpm (de Ridder, 2001)

Influent Concentration (mg/L)	Dissolved copper (nearest 10%)	Dissolved zinc (nearest 10%)
0.01 to 0.05	20 – 40	60 - 80
0.05 to 0.10	Inconclusive	50 - 70
0.10 to 0.50	60 – 80	60 - 80
0.50 to 1.00	No data	70 - 90
> 1.00	70 - 90	70 - 90

Additionally, Stormwater Management is claiming that XFCSF leaf media operating at 15 gpm will remove between 39 and 84% dissolved zinc at concentrations between 0.010 and 0.700 mg/L (Stormwater Management, 2002c).

(3) Total TPHs removal

Removal of TPH by media within the StormFilter cartridge is accomplished through adsorption. The cartridge with perlite media and CSF media separately was tested in the UCLA laboratory at full scale (Woodward-Clyde, 1998)

The cartridge was mounted in a catch basin and the unit was tested for 90 minutes at 15 gpm with influent oil and grease concentrations of 25 mg/L. The removal efficiency for free oil and grease was 69% for perlite media and 74% for CSF media (Woodward-Clyde, 1998).

5.3 Maintenance

Inspections of the StormFilter are performed during mid-season to determine loading on the system. The design maintenance frequency of the StormFilter is once per year. Frequency is determined through site evaluation as discussed below. Stormwater Management will contact the owner if early maintenance may be needed. All field site assessments (i.e. sediment accumulation, media condition/vault, etc) should be stored with maintenance records pertaining to each system. When one of the following conditions is observed, maintenance will be needed:

(1) Sediment accumulation on top of cartridge is an indication that the influent water is not passing through the cartridges at the design rate (i.e. suspended sediment has time to settle out rather than being filtered).

(2) Scum line in relation to height on vault wall. If the scum line is at or below the overflow elevation which is at the invert of the downstream flow spreader, then the system has not been loaded to the point where overflow has occurred.

(3) Accumulated sediment on the floor of 1/4" usually indicates full maintenance is not required. Sediment accumulations of l/2" or greater typically warrants full maintenance.

(4) If the cartridges are in standing water, this is direct evidence that the cartridges are completely plugged. However, the inspector needs to insure that the cartridges are not submerged due to backwater conditions caused by high ground water, plugged pipes or high hydraulic grade lines.

(5) Media appearance - Perlite media is extremely white when put in place. When this media becomes darkened to the point of almost being black, maintenance is needed. CSF Leaf media will become impacted with sediment such that no interstitial spaces are between the granulated media.

StormFilter maintenance is typically performed using a single cartridge pick (4" Schedule 80 PVC threaded end cap, provided by Stormwater Management) and a truck-mounted crane to remove the cartridges. After cartridge removal, accumulated sediments are removed using a square nose shovel and a large container.

The toxicity of the residues produced will depend on the activities in the contributing drainage area and testing of the sediment may be required to determine if it is considered hazardous. So far, no hazardous waste residues have been found in StormFilter installations and all disposals of cartridge media have been to non-hazardous landfills.

6. Technical Evaluation Analysis

6.1 Verification of Performance Claims

Based on the evaluation of the results from laboratory studies and field data, it appears that sufficient data is available to support Stormwater Management Claims 1, 2, and 3.

6.2 Limitations

StormFilter is best utilized for the removal of suspended solids in storm water. The StormFilter uses filter cartridges housed in concrete vaults to produce a self-contained storm water filtering system. The design life of the structure is typically 50 years. Cartridge life is guaranteed as long as the maintenance contract is upheld. Typical life of a cartridge has been budgeted at 20 years. Each cartridge is designed to treat a peak flow of 5 to15 gpm. Since storm water flows by gravity, the StormFilter typically requires 2.3 feet of head differential between the invert of the inlet and the invert of the outlet.

Water tightness of the concrete vault should be considered in the design. Most external joints are not subject to water from the inside or high groundwater from the outside. Internal joints should be sealed with grout and inspected during maintenance.

Backwater can be a problem if downstream hydraulic calculations are not performed properly. Backwater will reduce the hydraulic potential across the filter reducing flow rate through the cartridge. Backwater may also saturate media for long periods of time.

Baseflows should be bypassed to ensure proper functioning of the cartridges and the filtration media. If baseflows occur, the filtration media may become exhausted prematurely. This will affect the life of the cartridges and maintenance may be required more often. Low flow bypasses can be installed retroactively.

Excessive solids loading, hydrocarbon loading, and/or debris should be addressed during the design phase to assess if pretreatment is needed. Heavy solids loading without pretreatment can cause clogging of the cartridges. Maintenance frequency increases if this occurs.

The StormFilter design incorporates some ponding of water which can be a breeding site for mosquitoes. Also, if the cartridges plug due to inadequate maintenance, additional standing water will result.

Inspections should be performed during mid-season to determine sediment loading on the system. This involves mobilization to the site, documentation of media and vault conditions and measurements of accumulated sediments. Other inspections are performed during the year if a field crew is in the area of the filter and as time permits.

7. Net Environmental Benefit

The New Jersey Department of Environmental Protection (NJDEP or Department) encourages the development of innovative environmental technologies (IET) and has established a performance partnership between their verification/certification process and NJCAT's third party independent technology verification program. The Department in the IET data and technology verification/certification process will work with any New Jersey-based company that can demonstrate a net beneficial effect (NBE) irrespective of the operational status, class or stage of an IET. The NBE is calculated as a mass balance of the IET in terms of its inputs of raw materials, water and energy use and its outputs of air emissions, wastewater discharges, and solid waste residues. Overall the IET should demonstrate a significant reduction of the impacts to the environment when compared to baseline conditions for the same or equivalent inputs and outputs.

Once StormFilter has been recommended and verified for interim use within the State of New Jersey, Stormwater Management will then proceed to install and monitor systems in the field for the purpose of achieving goals set by the Tier II Protocol and final certification. At that time a net environmental benefit evaluation will be completed. However, it should be noted that the StormFilter technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

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